

PATENT ABSTRACTS OF JAPAN

(11)Publication number : 06-174447
 (43)Date of publication of application : 24.06.1994

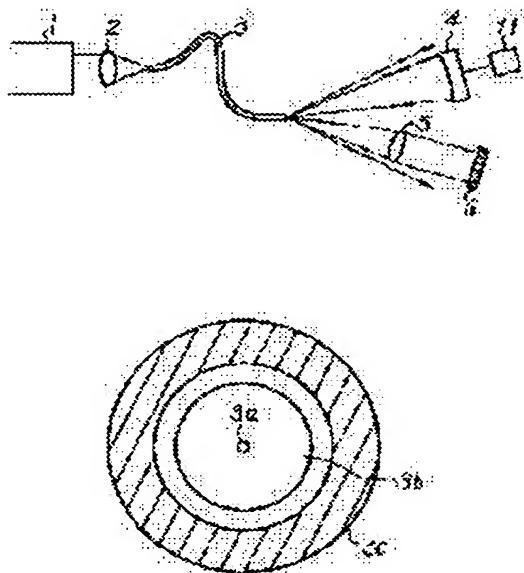
(51)Int.Cl. G01B 11/24
 G01B 9/02

(21)Application number : 04-343599 (71)Applicant : NIKON CORP
 (22)Date of filing : 01.12.1992 (72)Inventor : GENMA TAKASHI

(54) PROFILE IRREGULARITY MEASURING DEVICE

(57)Abstract:

PURPOSE: To attain high precision and miniaturize a device by emitting the outgoing light flux from a semiconductor laser via a solid light transmission line, and utilizing it as the measuring light flux and the reference light flux. CONSTITUTION: The outgoing light from a semiconductor laser light source 1 is directly fed to a single-mode optical fiber 3 with a lens 2, and it is sent out from an outgoing end face. The outgoing wave front is equal to the diffracted wave by a pinhole having the same size as the diameter of the core 3a of the fiber 3, and part of the outgoing light radiates a measurement face 4 as the measuring light flux. The light flux reflected on the measurement face 4 is again condensed on the outgoing end face of the fiber 3, it is reflected on a clad section 3b, and it is formed into the parallel light flux by a lens 5 and guided to the light receiving face of a CCD 6. The other part of the outgoing light from the fiber 3 is formed into the parallel light as the reference light flux by the lens 5, it is made to interfere with the measuring light flux by the CCD 6, and interference fringes are generated. The outgoing wave front is the nearly ideal spherical wave, and the profile irregularity can be measured with high precision at 1/100-1/1000 of the light wavelength λ .



LEGAL STATUS

[Date of request for examination] 04.10.1999
 [Date of sending the examiner's decision of rejection]
 [Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]
 [Date of final disposal for application]
 [Patent number] 3295993
 [Date of registration] 12.04.2002
 [Number of appeal against examiner's decision of rejection]
 [Date of requesting appeal against examiner's decision of rejection]
 [Date of extinction of right]

(19) 日本国特許庁 (JP)

(12) 公開特許公報 (A)

(11) 特許出願公開番号

特開平6-174447

(43) 公開日 平成6年(1994)6月24日

(51) Int. Cl. 5
G01B 11/24

識別記号 庁内整理番号

D 9108-2F

F I

M 9108-2F

技術表示箇所

9/02

審査請求 未請求 請求項の数4 (全7頁)

(21) 出願番号 特願平4-343599

(22) 出願日 平成4年(1992)12月1日

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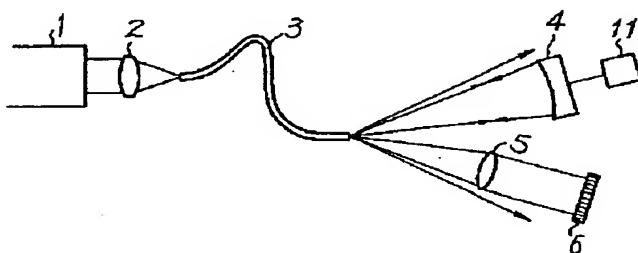
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(54) 【発明の名称】面精度測定装置

(57) 【要約】

【目的】 高精度の面精度測定装置の容易な実施化を図ること、並びに装置の小型化と応用の範囲の拡大を目的として、一般利用可能な構成からなる面精度測定装置を提供すること。

【構成】 被測定面で反射された測定用光束と、参照用光束とを互いに干渉させて生ずる干渉縞から球面精度を測定する面精度測定装置であって、光源手段が光源からの光束を伝達する固体光伝送路を有し、この光伝送路の光出射部から出射する光束を前記測定用光束及び参照用光束として利用するもの。



【特許請求の範囲】

【請求項1】 光源手段からの光束の照射位置に被測定面となる凹球面を配置し、この被測定面で反射された測定用光束と、参照用光束とを互いに干渉させ、該干渉により生ずる干渉縞の状態を検知することにより、前記被測定面の球面精度を測定する面精度測定装置において、前記光源手段の出射光束を伝達する固体光伝送路を有し、この光伝送路の光出射部から出射する光束を前記測定用光束及び参照用光束として利用することを特徴とする面精度測定装置。

【請求項2】 光源手段からの光束の照射位置に被測定面となる凹球面を配置し、この被測定面で反射された測定用光束と、参照用光束とを互いに干渉させ、該干渉により生ずる干渉縞の状態を検知することにより、前記被測定面の球面精度を測定する面精度測定装置において、前記光源手段が半導体レーザを含み、該半導体レーザから空間を介さずに直接出射される光束を前記測定用光束及び参照用光束として直接利用することを特徴とする面精度測定装置。

【請求項3】 前記半導体レーザから直接出射される測定用光束と参照用光束との光軸が、前記半導体レーザの光軸に対して互いに軸対称となるように構成されていることを特徴とする請求項2に記載の面精度測定装置。

【請求項4】 前記光源手段の光出射部近傍位置に光反射部を設けたことを特徴とする請求項1、2又は3に記載の面精度測定装置。

【発明の詳細な説明】

【0001】

【産業上の利用分野】 本発明は、凹球面の面精度を測定する面精度測定装置に関するものである。

【0002】

【従来の技術】 従来から球面の面精度を測定する装置としては、干渉計を応用したものが知られており、これらに応用される干渉計には、トワイマングリーン型干渉計、フィゾー型干渉計等がある。

【0003】 また、これらの干渉計を更に応用して、光源手段にピンホールからの回折光を用いる干渉計が特開平2-228505号として公開されている。この先行例では、光源からの光束をいったん集光させてピンホールに導き、ピンホールから出射される回折光を測定用光と参照用光とに利用するものとなっている。

【0004】

【発明が解決しようとする課題】 ところで、トワイマングリーン型干渉計、フィゾー型干渉計を面精度の測定に応用する場合には、測定精度を向上させるために、球面ゲージを用いて光学系の収差の影響を補正する必要があり、この球面ゲージ自体の絶対精度は、使用する測定用光束の波長 λ に対して、 $\lambda/40$ ($\lambda = 633$ nm) 程度である。しかしながら、近年、短波長光学素子、特に軟X線用の光学素子では、 $\lambda/100$ ～ $\lambda/1000$ (数10Å) 以下

の面精度が要求されており、従来の球面ゲージを用いる干渉計では、求められる精度に対応することができない問題が生じてきた。

【0005】 一方、先行例のようにピンホールからの回折光を用いる干渉計では、 $\lambda/100$ ～ $\lambda/1000$ という高い精度での測定が可能であるが、以下に示す問題から一般への利用がなされていない。まず、光源手段に用いるピンホールには、ミクロンオーダーの精密な精度が要求されるが、このようなピンホールの製作は極めて困難であり、製作してもコストがかかり過ぎる問題がある。

【0006】 さらに、このような微小なピンホールに対する光学系、特にピンホール照明系の位置決めには、レーザ光の集光が極めて精密な精度を要求されるため、このような光学系の制作はコストを含めて極めて困難である。また、光源として比較的安定性の良い半導体レーザなどを用いても、レーザ自体の振動や電気的条件の変動（ノイズ等）、並びに装置環境に対する磁界等の影響や、これらに基づく光源からの光束の位置のドリフト等を考慮する必要がある。このため、レーザ光の集光のビンスポットをピンホールの径よりもある程度余裕のある大きさにする必要があるので、ピンホール周辺（ピンホール以外）に集光される光量の損失が避けられない問題も生じていた。

20 【0007】 そこで、本発明では、従来の方式での上記の問題点を解決し、極めて高い精度を有する面精度測定装置の容易な実施化を図ること、並びに装置の小型化と応用の範囲の拡大を目的として、一般利用可能な構成からなる面精度測定装置を提供するものである。

【0008】

30 【課題を解決するための手段】 上記目的達成のため本願請求項1に記載の発明は、光源手段からの光束の照射位置に被測定面となる凹球面を配置し、この被測定面で反射された測定用光束と、参照用光束とを互いに干渉させ、該干渉により生ずる干渉縞の状態を検知することにより、前記被測定面の面精度を測定する面精度測定装置において、光源手段の出射光束を伝達する固体光伝送路を設け、この光伝送路の光出射部から出射する光束を前記測定用光束及び参照用光束として利用するものである。

40 【0009】 また、請求項2に記載の発明では、光源手段からの光束の照射位置に被測定面となる凹球面を配置し、この被測定面で反射された測定用光束と、参照用光束とを互いに干渉させ、該干渉により生ずる干渉縞の状態を検知することにより、前記被測定面の面精度を測定する面精度測定装置において、前記光源手段を半導体レーザにより構築し、該光源から半導体レーザから空間を介さずに直接出射される光束を前記測定用光束及び参照用光束として直接利用するものである。

50 【0010】 さらに、請求項3に記載の発明では、請求項2に記載の面精度測定装置において、前記半導体レー

ザから直接出射される測定用光束と参照用光束との光軸を、前記半導体レーザの光軸に対して互いに軸対称となるように構成したものである。

【0011】更にまた、請求項4に記載の発明では、請求項1、2又は3に記載の面精度測定装置において、前記光源手段の光出射部近傍位置に光反射部を設けたことを特徴とする。

【0012】

【作用】本発明は、上記のように構成されているため以下の作用を奏する。まず、請求項1に記載の発明では、例えば光ファイバーや光導波路等からなる固体光伝送路を有しており、光源からの光束をこの固体光伝送路の一端に入射させて他方の出射端から出射させる。ここで、この出射端の大きさを適当に定めることでここから出射される光束は球面波となって放射状に広がりを持つものとなる。

【0013】出射光の一部は測定用光束として前記被測定面に照射され、他の一部の光束は参照用光束として利用される。そして、被測定面で反射された測定用光束と参照用光束とは互いに干渉を起こすように導かれる。即ち、概略すればこの固体光伝送路の出射端からの光束を利用した干渉計としての機能を応用した面精度測定装置となる。

【0014】したがって、この発明では光源手段に先行例のようなミクロンオーダーの精密なピンホールを製作する必要がなく、固体光伝送路として例えば光ファイバーを用いる場合には、コア径が数ミクロンの单一モードファイバーを用いればよく、市販の製品をそのまま用いることもできる。さらに、例えば光ファイバーへの光の入射には、やはり市販の光結合素子を用いることができるため、先行例のように集光に関する問題点を解消し、極めて容易に光ファイバーへの光の入射が行える。この点は、固体光伝送路として例えば光導波路を用いた場合にもほぼ同様であり、先行例等と比較して光源手段の光学系が簡略な構成となる。

【0015】なお、例えば光導波路を固体光伝送路として用いた場合には、光源として半導体レーザを用いれば、光源手段を構成する半導体レーザと光導波路とを同一の基板上に形成して一体化することが可能であり、コンパクトに集積された光源手段を利用して、装置全体が小型・軽量化された安定な面精度測定装置となる。

【0016】一方、本発明では光源手段における固体光伝送路の出射端自体を疑似光源と考えることができるのと、本来の光源が干渉計を構成する部材から離れた位置に任意に構成できるので、装置の設計上の自由度が増加して干渉計としての利用範囲も拡大し、例えば光学部品製作現場等での利用も可能になる。

【0017】又、請求項2に記載の発明では、光源手段として半導体レーザ光源からの出射光を空間を介すことなく直接用いることにより、上記の課題を達成してい

る。即ち、本発明では半導体レーザから出射した光の一部をそのまま測定用光束として被測定面に照射するとともに、半導体レーザから出射した光の他の一部を参照用光束として直接利用する。そして、被測定面で反射された測定用光束と参照用光束とを互いに干渉させて、簡単な構成の干渉計を応用した面精度測定装置を実現している。

【0018】ここで、半導体レーザは、光出射部が極めて微小（構造により0.1～20μm）であり、この光出射部から略放射状に球面波を射出する。このため、本発明では上記の発明の光出射部の代わりに、半導体レーザからの光束を直接そのまま測定用及び参照用光束として利用することで、上記発明同様に干渉計の作用を利用して面精度を測定できるものとなっている。

【0019】更に、請求項1に記載の発明では、固体光伝送路として光導波路を使用した場合に、導波路上で位相変調を行うことが可能であり、また、請求項2に記載の発明では、半導体レーザの波長を変調することで、各々測定用光束の波長を変更することが可能であり、これららの変調手段を設ければピエゾ素子等の可動部を必要としない、いわゆるAC干渉計を実現することが出来る。

【0020】ところで、一般的な半導体レーザからの出射光は、光軸に対して理想的な球面ではなく非点収差を持った波面である場合が多い。このため、本発明にはできるだけ非点収差の少ない半導体レーザを用いることが好ましいが、製造コスト等の問題からこのような非点収差を持った光源の使用を余儀なくされる場合がある。このような場合に非点収差の影響を排除する必要があり、請求項3に記載した発明は、この点を考慮したものである。

【0021】請求項3に記載した発明では、半導体レーザからなる光源手段から直接出射される測定用光束と参照用光束との光軸が、前記半導体レーザの光軸に対して互いに軸対称となるように構成されている。これにより、半導体レーザの光軸に対して反転対象となる非点収差は、軸対称に配置された測定用光束と参照用光束との光軸の関係から互いに相殺されることとなり、非点収差の存在が測定上問題とならないものとなる。

【0022】次に、請求項4に記載した発明では、上記の各発明において、光源手段の光出射部近傍位置に光反射部を設けているため、被測定面で反射した測定用光束がこの光反射部で再度反射されて参照用光束と同軸に導かれる。この反射部を設けない場合には、請求項1に記載の発明では、固体光伝送路の光出射部の周辺部（例えば、光ファイバーのグラッド部、光導波路の基板端面等）で測定用光束を反射させることとなるが、これらの周辺部では反射率が低いので、干渉縞のコントラストが低下して希望する検出精度が得られない場合がある。本発明はこのような問題を解消するものであり、光反射部を設けることで被測定面からの測定用光束の反射率を向

上させ、干渉縞を形成する（干渉光の一方となる）測定用光束の強度を向上させる。

【0023】この光反射部は、例えば請求項1記載の発明で光ファイバーを使用した場合には、コア部を除いた周辺部を鏡面加工することで形成することができ、又、請求項2記載の発明における半導体レーザの光出射部以外の近傍位置に鏡面加工をすることでも形成することができる。なお、光反射部は鏡面に限らず、表面コーティング等により反射効率を高めたものでも良い。

【0024】

【実施例】以下実施例を通じ本発明をさらに詳しく説明する。図1は本発明の第1の実施例に係る鏡面精度測定装置の概略構成並びに光路を示す概念図である。この実施例では、レーザ光源1から出射した光をレンズ2により単一モード光ファイバー3に入射させる。実際にはレンズ2を中心とした光結合素子により、レーザ光源1からの光束は効率よく（ほぼ100%）入射端面から単一モード光ファイバー3内に導かれる。そして、単一モード光ファイバー3内を平行光の形で透過し、別の端面（出射端面）から出射する。

【0025】この出射波面は、単一モード光ファイバー3のコア3a径に等しい大きさのピンホールによる回折波と等しく、ある条件（後述）のもとでは理想的な球面波とみなすことが出来る。そして、この出射光の一部は測定用光束として被測定面4を照射する。この被測定面4の光軸（測定用光束の光軸）は、光ファイバー3の光軸と所定の角度をなして配置されており、さらに、光ファイバー3の出射端面の位置は被測定面4を構成する球面の曲率中心の位置と一致させることができるものである。

【0026】被測定面4で反射された測定用光束は、元来た光路を通って光ファイバー3の出射端面に再度集光される。この際、集光された測定用光束は、光ファイバー3のクラッド部3b、或はその外側の固定用治具3cの端面で反射され、レンズ5で平行光束となり、CCD6の受光面に到達する。一方、光ファイバー3からの出射光の他の一部は、参照用光束としてやはりレンズ5で平行光とされてCCD6に到達する。そして、CCD6の受光面では、参照用光束と被測定面4並びに光ファイバー3の出射端面で反射された測定用光束とが互いに干渉して干渉縞を生じる。

【0027】また、本実施例では、測定精度を向上させるために、被測定面4のホルダにピエゾ素子11が配設されており、被測定面4を光軸方向に微小に振動させて、周知のAC干渉計の手法により高精度に被測定面4の面精度を読み取ることが出来るようになっている。

【0028】なお、本実施例では、測定用光束と参照用光束との光路長が異なるが、光源1として单一波長レーザ等の可干渉性の良い光源を使用すれば、この程度の光路長の差は測定上問題にならない。

【0029】ところで、本実施例の測定精度は、光ファ

イバー3からの出射光の出射波面の精度で決まる。ここで、光ファイバーのコアの径（直径） ϕ が、使用波長 λ 、被測定面の曲率半径を r 、その口径を a とするとき、以下の(1)式の関係を満たしていれば、ここからの出射波面は理想的な球面波とみなすことができるので、 $\lambda/100 \sim \lambda/1000$ という高い精度で面精度を測定することができる。

【0030】

$$\lambda/2 < \phi < \lambda r / 2a \quad (1)$$

10 【0031】したがって、この(1)式の条件から本実施例では、単一モード光ファイバー3のコア3aの径を $\phi = 6 \mu m$ 、 $\lambda = 0.6 \mu m$ とすると、被測定面4との関係は、 r/a が20以上であることが条件となる。

【0032】次に、本実施例の単一モード光ファイバー3は図2に示すように、直径数 μm のコア3a、直径 $100 \mu m$ 程度のクラッド3bからなり、光コネクタ用等の固定用治具3c内に固定されている。そして、前述したように被測定面4で反射された測定用光束は、光ファイバー出射端面のクラッド3b近傍で反射される。

20 【0033】この測定用光束は、被測定面4とファイバー端面との2つの面で（一部のみ）反射されるため、1度も反射されていない参照用光束に比べ光量が減衰しており、CCD6の受光面に生じる干渉縞のコントラストが低くなる。この場合には、ピエゾ素子を稼動させてAC干渉計の手法を用いれば、低いコントラストの干渉縞も測定可能である。

【0034】しかし、あまりに低いコントラストは測定精度を悪化させる要因となるので、測定用光束の反射効率を高めることで、干渉縞のコントラスト（測定用光束の光量）を向上させることが考えられる。このため、他の実施例では光ファイバー端面のクラッド部にコーティング（図示せず）をし、反射率を高めることでこの問題の解決を図っている。また、金属性の固定用治具3c表面は高い反射率を持つので、これを光反射部として測定用光束をここで反射させてもよい。いずれにせよ、光ファイバー端面部の測定用光束を反射する部分は、そのスポットの範囲内で十分良い面精度であることが必要である。

30 【0035】以上のように本実施例によれば、光源1からの光束を無駄なく利用することができると共に、先行例のようにピンホールを使用しないため、光学系自体を簡素化できるものとなっている。また、レーザ光特有のドリフト等に伴う光源の安定性や光量損失等の問題も解消され、極めて高い精度で面精度を測定することが出来る面精度測定装置となっている。

【0036】加えて、本実施例によれば、測定装置並びに干渉計の構成を非常にフレキシブルにすることができる利点がある。例えば、本実施例の光ファイバーを長くすれば、光源1から十分に離れた場所で面精度の測定を行なうことが可能であり、光源部の大きさに影響されない

コンパクトな干渉計を構成することが出来る。さらにこの場合には、光源 1 を干渉計部分から離すことで、光源 1 の発熱、振動等の影響を被測定面に与えない安定した測定装置を構成することが可能になった。

【0037】また、光ファイバーとして、偏波面保存ファイバーを用いれば、光源 1 の偏光状態を保った状態での光束を測定に利用することができるものとなる。この場合には、面精度のみならず、偏光した光束に基づく複屈折作用等を応用して、例えば球面の表面に施されたコーティング部材の厚み（均一性）の測定等に応用することも可能である。

【0038】次に、固体光伝送路として光導波路を用いた実施例を図 3 に示す。この実施例では、基板上に単一モード導波路 37 が設けられており、この導波路部の大きさは数ミクロンに形成されている。そして、ここから出射される光束を用いることで、前述した単一モード光ファイバーを用いるのと同様な作用を得ることができる。なお、本実施例における被測定面 4、レンズ 5、ピエゾ素子 11 並びにこれらの配置構成は上記実施例と同様である。

【0039】ところで、図 3 に示す実施例では、レーザ光源 31 からの光を光集光素子 32 を介して光導波路 37 に入射させているが、光源として半導体レーザを用いることも可能であり、この場合にはレンズを介さずダイレクトに光源と光導波路 37 を結合することも可能である。さらに、光導波路 37 の基板上に半導体レーザをモノリシックに一体化することも可能であり、光源手段の集積化による小型化が図れるものとなる。なお、いずれの場合でも光源には可干渉性の良い光源を用いることは言うまでもない。

【0040】また、導波路基板上に電極を設けて光導波路 37 上で位相変調を行うことで、ピエゾ素子を用いずにいわゆる A C 干渉計の手法を用いることも出来る。

【0041】このように、本実施例並びにその応用例によれば、非常に小型な測定装置を形成することが可能であり、特に、CCD 6 等の検出手段を用いずに直接目視で干渉縞を観察するだけであれば、半導体レーザ光源と光導波路だけからなる大きさ数 mm の超小型測定装置が実現できる。

【0042】次に、本発明の他の実施例として、光源からの出射光を直接用いる実施例にかかる球面形状測定装置の概略構成を図 4 に示す。この実施例では、光源として半導体レーザ 48 を利用し、この半導体レーザ 48 からの出射光を直接測定用光束並びに参照用光束に利用している。なお、本実施例における被測定面 4、レンズ 5、ピエゾ素子 11 並びにこれらの配置構成も上記実施例と同様である。

【0043】図 4 に示すように本実施例では、半導体レーザ 48 から出射した出射光束の一部がそのまま測定用光束として半導体レーザ 48 の光軸と所定の角度をなし

て置かれた被測定面 4 を直接照射する。被測定面 4 で反射された測定用光束は、元来た光路を通って半導体レーザ 48 の出射端面に集光される。そして、この集光された光は、半導体レーザ 48 の端面で再度反射され、レンズ 5 で平行光束となり、CCD 6 の受光面に到達する。また、半導体レーザ 48 からの出射光束の他の一部は、そのまま参照用光束としてレンズ 5 で平行光とされて CCD 6 に直接到達する。そして、CCD 6 の受光面では、参照用光束と被測定面 4 で反射された測定用光束とが互いに干渉して干渉縞が生じる。

【0044】ところで、一般的な半導体レーザの出射光（出射波面）は、理想的な球面波ではなく非点収差を持った波面であることが知られているが、最近では非点収差の少ない半導体レーザが開発されており、全く非点収差のない面発光レーザの開発も進められているので、本干渉計にはこうしたものを用いることが望ましい。

【0045】しかし、一般的な半導体レーザを利用する場合には、出射光束における非点収差が半導体レーザの光軸に対して反転対称であることをを利用して、被測定面 4 の光軸と半導体レーザ 8 の光軸のなす角を、レンズ 5 の光軸と半導体レーザ 8 の光軸のなす角と等しくすることで、非点収差を相互にキャンセルすることが可能であり、これらの非点収差の存在は実際には問題にならないものとなる。

【0046】ここで、一般的なダブルヘテロ接合の半導体レーザを例にとって、ここから出射される光の状態を図 5 に示す。この図に示すように、半導体レーザからの出射光は、活性層に垂直な方向（z 方向）に大きな広がり角（40 ~ 60°）を持ち、水平方向（y 方向）には小さな広がり（約 10°）を持つ。このため、本実施例のように非点収差を打ち消す目的を達成する場合には、各部材の配置を考慮すると、測定用光束（被測定面 4）の光軸を半導体レーザの活性層と垂直な方向に傾けると共に、参照用光束（レンズ 5）の光軸をそれと対称な方向に傾けることが好ましい。

【0047】さらに、半導体レーザ 48 の出射端面は、通常波長以上の精度で研磨されているため反射効率はかなり高いものとなるが、光出射部を除いて鏡面加工を施すことで被測定面 4 で反射してきた測定用光束を効率よく反射させることができるので、干渉縞の測定が容易となる。

【0048】また、本実施例に係る測定装置でも、ピエゾ素子 11 により被測定面を光軸方向に微小に振動させて、周知の A C 干渉計の手法により高精度に被測定面の面精度を読み取ることが出来るものとなっている。ここで、半導体レーザ 48 の波長を変調することによっても A C 干渉計の手法を用いることが可能であり、この場合には全く架動部のない測定装置が構成できる。

【0049】なお、本実施例でも測定用光束と参照用光束の光路長が異なるが、半導体レーザ光源 48 は一般的

に単一波長レーザであり可干渉性の良い光源であるため、この程度の光路長の差は問題にならない。

【0050】以上のように、本実施例によれば、光源8と干渉縞結像系となるレンズ5並びにCCD6だけからなる最もシンプルな構成の測定装置を構築することが可能である。

【0051】

【発明の効果】以上説明したように本発明によれば、従来の一般的な干渉計を応用した装置のように、球面ゲージを用いて光学系の収差の影響を補正する必要はなく、これらの装置では得られなかつた高い精度での面精度が測定できる利点がある。

【0052】一方、先行例のように精密なピンホールの製作上の問題や、これを利用する光学系の精密な位置合わせや、これらに伴う光源の光量損失や安定性等の諸問題が解消されており、光源手段の光学系が簡略な構成となるので、一般実施が極めて容易に行える。

【0053】さらに、固体光伝送路として市販の光ファイバー等を簡単に利用でき、光源にも市販の半導体レーザをそのまま用いることができるので、製造コストも大幅に減少しその製作工程も簡素化できるものとなっている。加えて、光源と光ファイバーや光導波路等の固体光伝送路を一体に設けて集積化することにより小型で扱い易い面精度測定装置を実現できる。

【0054】また、固体光伝送路を延長すれば、光源を装置の干渉縞結像系から離れた位置に配設することが可能であり、設計の自由度が向上すると共に干渉計の利用範囲が拡大し、例えばレンズ等の製作現場での利用が容易となる。さらに、この場合には干渉縞結像系等へ光源の振動等の影響を排除できるため、測定精度の誤差が生じにくいものとなる。

【図面の簡単な説明】

【図1】本発明の第1の実施例に係る面精度測定装置を示す説明図である。

【図2】本発明の第1の実施例に係る面精度測定装置における光ファイバーの出射端面を示す説明図である。

【図3】本発明の第2の実施例に係る面精度測定装置を示す説明図である。

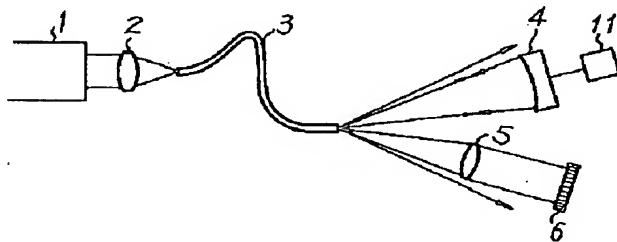
【図4】本発明の第3の実施例に係る面精度測定装置を示す説明図である。

【図5】半導体レーザの構造並びに射出光束の状態を示す説明図である。

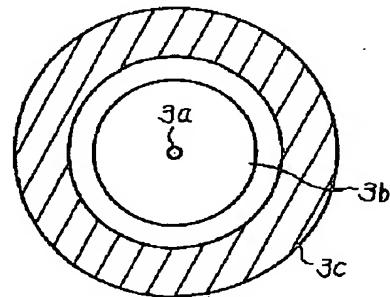
【符号の説明】

1, 31…光源、48…半導体レーザ、2, 32…集光レンズ（光集光素子）、3…光ファイバー、3a…コア、3b…グラッド、3c…固定治具、37…光導波路、4…被測定面（凹球面）、5…レンズ、6…CCD、11…ピエゾ素子、

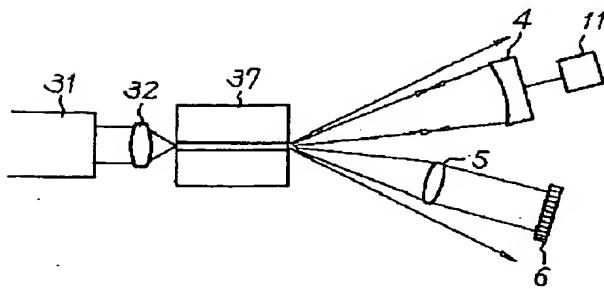
【図1】



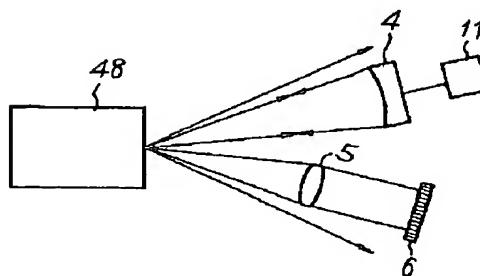
【図2】



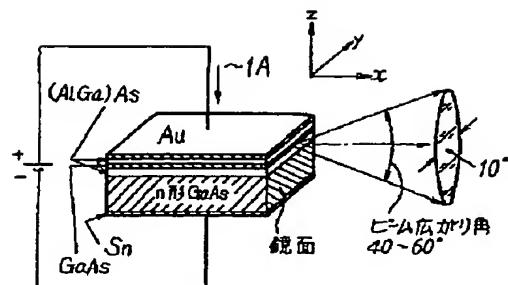
【図3】



【図4】



【図 5】



PATENT ABSTRACTS OF JAPAN

(11)Publication number : 06-174447
 (43)Date of publication of application : 24.06.1994

(51)Int.CI. G01B 11/24
 G01B 9/02

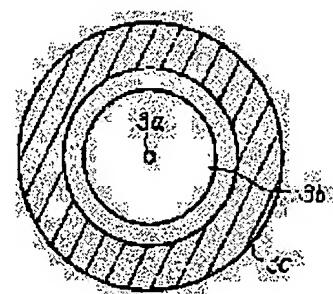
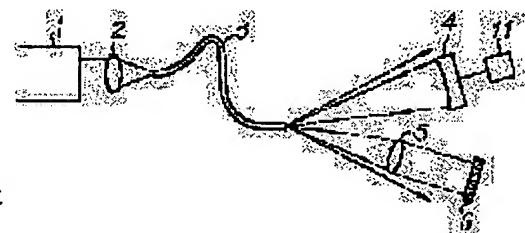
(21)Application number : 04-343599 (71)Applicant : NIKON CORP
 (22)Date of filing : 01.12.1992 (72)Inventor : GENMA TAKASHI

(54) PROFILE IRREGULARITY MEASURING DEVICE

(57)Abstract:

PURPOSE: To attain high precision and miniaturize a device by emitting the outgoing light flux from a semiconductor laser via a solid light transmission line, and utilizing it as the measuring light flux and the reference light flux.

CONSTITUTION: The outgoing light from a semiconductor laser light source 1 is directly fed to a single-mode optical fiber 3 with a lens 2, and it is sent out from an outgoing end face. The outgoing wave front is equal to the diffracted wave by a pinhole having the same size as the diameter of the core 3a of the fiber 3, and part of the outgoing light radiates a measurement face 4 as the measuring light flux. The light flux reflected on the measurement face 4 is again condensed on the outgoing end face of the fiber 3, it is reflected on a clad section 3b, and it is formed into the parallel light flux by a lens 5 and guided to the light receiving face of a CCD 6. The other part of the outgoing light from the fiber 3 is formed into the parallel light as the reference light flux by the lens 5, it is made to interfere with the measuring light flux by the CCD 6, and interference fringes are generated. The outgoing wave front is the nearly ideal spherical wave, and the profile irregularity can be measured with high precision at 1/100–1/1000 of the light wavelength λ .



LEGAL STATUS

[Date of request for examination] 04.10.1999

[Date of sending the examiner's decision of rejection]

[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]

[Date of final disposal for application]

[Patent number] 3295993

[Date of registration] 12.04.2002

[Number of appeal against examiner's decision of rejection]

[Date of requesting appeal against examiner's decision of rejection]

[Date of extinction of right]

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CLAIMS**[Claim(s)]**

[Claim 1] By arranging the concave spherical surface used as a measuring plane-ed in an exposure location of the flux of light from a light source means, making the flux of light for measurement reflected by this measuring plane-ed, and the flux of light for reference interfere mutually, and detecting a condition of an interference fringe produced by this interference A profile irregularity measuring device characterized by using the flux of light which has a solid-state optical transmission line which transmits an outgoing beam of said light source means in a profile irregularity measuring device which measures spherical-surface precision of said measuring plane-ed, and carries out outgoing radiation from the optical outgoing radiation section of this optical transmission line as said flux of light for measurement, and the flux of light for reference.

[Claim 2] By arranging the concave spherical surface used as a measuring plane-ed in an exposure location of the flux of light from a light source means, making the flux of light for measurement reflected by this measuring plane-ed, and the flux of light for reference interfere mutually, and detecting a condition of an interference fringe produced by this interference A profile irregularity measuring device characterized by using directly the flux of light by which direct outgoing radiation is carried out in a profile irregularity measuring device which measures spherical-surface precision of said measuring plane-ed, without said light source means minding space from this semiconductor laser including semiconductor laser as said flux of light for measurement, and the flux of light for reference.

[Claim 3] A profile irregularity measuring device according to claim 2 characterized by being constituted so that an optical axis of the flux of light for measurement and the flux of light for reference by which direct outgoing radiation is carried out may serve as axial symmetry from said semiconductor laser mutually to an optical axis of said semiconductor laser.

[Claim 4] A profile irregularity measuring device according to claim 1, 2, or 3 characterized by preparing the light reflex section in a location near the optical outgoing radiation section of said light source means.

[Translation done.]

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Industrial Application] This invention relates to the profile irregularity measuring device which measures the profile irregularity of the concave spherical surface.

[0002]

[Description of the Prior Art] As equipment which measures the profile irregularity of the spherical surface, the thing adapting an interferometer is known from the former, and there are a TOWAI man green mold interferometer, the Fizeau mold interferometer, etc. as interferometer applied to these.

[0003] Moreover, these interferometers are applied further and the interferometer which uses the diffracted light from a pinhole for a light source means is exhibited as JP,2-228505,A. In this example of precedence, the flux of light from the light source was made to once condense, it led to the pinhole, and the diffracted light by which outgoing radiation is carried out from a pinhole is used for the light for measurement, and the light for reference.

[0004]

[Problem(s) to be Solved by the Invention] By the way, in applying a TOWAI man green mold interferometer and the Fizeau mold interferometer to measurement of profile irregularity, in order to raise the accuracy of measurement, it is necessary to use a spherical-surface gage and to amend the effect of the aberration of optical system, and precision is $\lambda/40$ ($\lambda=633$ nm) degree to the wavelength λ of the flux of light for measurement of this spherical-surface gage itself to be used absolutely. However, at a recent-years and short wave Nagamitsu study element, especially the optical element for soft X ray, it is $\lambda / 100 - \lambda/1000$. The following (several 10A) profile irregularity is demanded, and the problem which cannot respond to the precision searched for has arisen in the interferometer using the conventional spherical-surface gage.

[0005] On the other hand, with the interferometer using the diffracted light from a pinhole like the example of precedence, it is $\lambda / 100 - \lambda/1000$. Although measurement in a high precision to say is possible, utilization general from the problem shown below is not made. First, although a precise precision of micron order is required of the pinhole used for a light source means, even if the fabrication of such a pinhole is very difficult and it manufactures it, it has the problem which requires cost too much.

[0006] Furthermore, since a very precise precision is required of condensing of a laser beam by positioning of the optical system over such a minute pinhole, especially a pinhole illumination system, work of such optical system is very difficult for it including cost. Moreover, even if it uses semiconductor laser with comparatively sufficient stability etc. as the light source, it is necessary to take into consideration the effect of the magnetic field over equipment environment etc., the drift of the location of the flux of light from the light source based on these, etc. in the oscillation of the laser itself, fluctuation (noise etc.) of electric conditions, and a list. For this reason, since pin spot of condensing of a laser beam needed to be made into the magnitude which is to some extent generous from the path of a pinhole, the problem on which loss of the quantity of light condensed around a pinhole (except a pinhole) is not avoided had also been produced.

[0007] So, in this invention, the above-mentioned trouble in the conventional method is solved, and attaining easy operation-ization of the profile irregularity measuring device which has a very high precision, and the profile irregularity measuring device which becomes a list from a general available configuration for the purpose of the miniaturization of equipment and amplification of the range of applied are offered.

[0008]

[Means for Solving the Problem] For the above-mentioned object achievement, invention of a publication to this application claim 1 By arranging the concave spherical surface used as a measuring plane-ed in an exposure location of

the flux of light from a light source means, making the flux of light for measurement reflected by this measuring plane-ed, and the flux of light for reference interfere mutually, and detecting a condition of an interference fringe produced by this interference In a profile irregularity measuring device which measures profile irregularity of said measuring plane-ed, a solid-state optical transmission line which transmits an outgoing beam of a light source means is prepared, and the flux of light which carries out outgoing radiation from the optical outgoing radiation section of this optical transmission line is used as said flux of light for measurement, and the flux of light for reference.

[0009] Moreover, the flux of light for measurement which has arranged the concave spherical surface used as a measuring plane-ed in an exposure location of the flux of light from a light source means, and was reflected in it by this measuring plane-ed in invention according to claim 2, By making the flux of light for reference interfere mutually, and detecting a condition of an interference fringe produced by this interference In a profile irregularity measuring device which measures profile irregularity of said measuring plane-ed, said light source means is built by semiconductor laser, and the flux of light by which direct outgoing radiation is carried out from this light source, without minding space from semiconductor laser is directly used as said flux of light for measurement, and the flux of light for reference.

[0010] Furthermore, in a profile irregularity measuring device according to claim 2, an optical axis of the flux of light for measurement and the flux of light for reference by which direct outgoing radiation is carried out from said semiconductor laser consists of invention according to claim 3 so that it may become axial symmetry mutually to an optical axis of said semiconductor laser.

[0011] Furthermore, by invention according to claim 4, it is characterized by preparing the light reflex section in a location near the optical outgoing radiation section of said light source means again in a profile irregularity measuring device according to claim 1, 2, or 3.

[0012]

[Function] Since this invention is constituted as mentioned above, it does the following operations so. First, in invention according to claim 1, it has the solid-state optical transmission line which consists of an optical fiber, optical waveguide, etc., for example, and incidence of the flux of light from the light source is carried out to the end of this solid-state optical transmission line, and outgoing radiation is carried out from the outgoing radiation edge of another side. Here, the flux of light by which outgoing radiation is carried out from here by defining the magnitude of this outgoing radiation edge suitably serves as a spherical wave, and has breadth in a radial.

[0013] A part of outgoing radiation light is irradiated by said measuring plane-ed as the flux of light for measurement, and a part of [other] flux of lights are used as the flux of light for reference. And the flux of light for measurement and the flux of light for reference which were reflected by the measuring plane-ed are drawn so that interference may be caused mutually. That is, if an outline is carried out, it will become a profile irregularity measuring device adapting the function as an interferometer in which the flux of light from the outgoing radiation edge of this solid-state optical transmission line was used.

[0014] Therefore, in this invention, when it is not necessary to manufacture the precise pinhole of micron order like the example of precedence for a light source means and uses an optical fiber as a solid-state optical transmission line, a commercial product can also be used as it is that what is necessary is just to use the single mode fiber whose core diameter is several microns. Furthermore, since a commercial optical coupling element can be used too, the trouble about condensing is canceled to the incidence of the light to an optical fiber like the example of precedence, and incidence of the light to an optical fiber can be carried out, for example to it very easily. This point is also almost the same as when optical waveguide is used as a solid-state optical transmission line, and the optical system of a light source means serves as a simple configuration as compared with the example of precedence etc.

[0015] In addition, if semiconductor laser is used as the light source when optical waveguide is used as a solid-state optical transmission line, for example, it will be possible to form the semiconductor laser and optical waveguide which constitute a light source means on the same substrate, and to unify, and the whole equipment will turn into a lightweight [small and]-ized stable profile irregularity measuring device using the light source means accumulated by the compact.

[0016] Since it can constitute at arbitration in the location where the original light source separated from the member which constitutes an interferometer on the other hand since the outgoing radiation edge of the solid-state optical transmission line in a light source means itself was considered to be the false light source by this invention, the flexibility on layout of equipment increases, and the utilization range as an interferometer is also expanded, for example, the utilization in an optic fabrication site etc. is also attained.

[0017] Moreover, in invention according to claim 2, the above-mentioned technical problem is attained by using the outgoing radiation light from the semiconductor laser light source directly through space as a light source means. That is, in this invention, while irradiating a measuring plane-ed as it is by making into the flux of light for measurement a

part of light which carried out outgoing radiation from semiconductor laser, a part of other light which carried out outgoing radiation from semiconductor laser is directly used as the flux of light for reference. And the flux of light for measurement and the flux of light for reference which were reflected by the measuring plane-ed were made to interfere mutually, and the profile irregularity measuring device adapting the interferometer of an easy configuration is realized. [0018] Here, the optical outgoing radiation section is minute (it is 0.1-20 micrometers by structure) very much, and semiconductor laser injects a spherical wave from this optical outgoing radiation section to an abbreviation radial. For this reason, in this invention, profile irregularity can be measured like the above-mentioned invention instead of the optical outgoing radiation section of the above-mentioned invention using the operation of an interferometer by using the flux of light from semiconductor laser as the object for measurement, and the flux of light for reference as it is directly.

[0019] Furthermore, in invention according to claim 1, when optical waveguide is used as a solid-state optical transmission line, it is possible to perform a phase modulation a waveguide on the street, and it is possible to change the wavelength of the flux of light for measurement respectively in modulating the wavelength of semiconductor laser in invention according to claim 2, and if these modulation means are established, the so-called AC interferometer which does not need moving part, such as a piezo-electric element, can be realized.

[0020] By the way, the outgoing radiation light from general semiconductor laser is the wave front which had not the ideal spherical surface but astigmatism to the optical axis in many cases. For this reason, although it is desirable to use semiconductor laser with as much as possible little astigmatism for this invention, it may be obliged to the activity of the light source which had such astigmatism from problems, such as a manufacturing cost. In such a case, invention which needed to eliminate the effect of astigmatism and was indicated to claim 3 takes this point into consideration.

[0021] It consists of invention indicated to claim 3 so that the optical axis of the flux of light for measurement and the flux of light for reference by which direct outgoing radiation is carried out may serve as axial symmetry from the light source means which consists of semiconductor laser mutually to the optical axis of said semiconductor laser. Thereby, the astigmatism which serves as an object for reversal to the optical axis of semiconductor laser will be mutually offset from the relation of the optical axis of the flux of light for measurement and the flux of light for reference which have been arranged at axial symmetry, and existence of astigmatism does not pose a measurement top problem.

[0022] Next, in invention indicated to claim 4, in each above-mentioned invention, since the light reflex section is prepared in the location near the optical outgoing radiation section of a light source means, it is again reflected in this light reflex section, and the flux of light for measurement reflected by the measuring plane-ed is led to the flux of light for reference, and the same axle. When not preparing this reflective section, the flux of light for measurement is made reflected by invention according to claim 1 by the peripheries (for example, the GURADDO section of an optical fiber, the substrate end face of optical waveguide, etc.) of the optical outgoing radiation section of a solid-state optical transmission line, but since the reflection factor is low in these peripheries, the detection precision for which the contrast of an interference fringe falls and wishes may not be acquired. This invention solves such a problem, raises the reflection factor of the flux of light for measurement from a measuring plane-ed by preparing the light reflex section, and raises the reinforcement of the flux of light for measurement (it becomes one side of an interference light) which forms an interference fringe.

[0023] When an optical fiber is used, for example by invention according to claim 1, this light reflex section can be formed by carrying out mirror plane processing of the periphery except the core section, and carrying out mirror plane processing can also form it in near locations other than the optical outgoing radiation section of the semiconductor laser in invention according to claim 2. In addition, what raised reflective effectiveness not only by the mirror plane but by surface coating etc. is sufficient as the light reflex section.

[0024]

[Example] This invention is explained in more detail through an example below. Drawing 1 is the conceptual diagram showing an optical path in the outline configuration list of the mirror plane precision measuring device concerning the 1st example of this invention. In this example, incidence of the light which carried out outgoing radiation from the laser light source 1 is carried out to a single mode optic fiber 3 with a lens 2. By the optical coupling element centering on a lens 2, the flux of light from a laser light source 1 is actually drawn in a single mode optic fiber 3 from an incidence end face efficiently (about 100%). And the inside of a single mode optic fiber 3 is penetrated in the form of parallel light, and outgoing radiation is carried out from another end face (outgoing radiation end face).

[0025] This outgoing radiation wave front is equal to the diffracted wave by the pinhole of magnitude equal to the diameter of core 3a of a single mode optic fiber 3, and it can be considered under some conditions (after-mentioned) that it is an ideal spherical wave. And a part of this outgoing radiation light irradiates the measuring plane 4-ed as the flux of light for measurement. The optical axis (optical axis of the flux of light for measurement) of this measuring plane 4-ed

makes an angle the optical axis of an optical fiber 3, and predetermined, and is arranged, and, as for the location of the outgoing radiation end face of an optical fiber 3, it is still more desirable to make it in agreement with the location of the center of curvature of the spherical surface which constitutes the measuring plane 4-ed.

[0026] The flux of light for measurement reflected by the measuring plane 4-ed is again condensed by the outgoing radiation end face of an optical fiber 3 through the optical path which came origin. Under the present circumstances, it is reflected by the end face of clad section 3b of an optical fiber 3, or fixture 3c for immobilization of that outside, and the condensed flux of light for measurement turns into the parallel flux of light with a lens 5, and arrives at the light-receiving side of CCD6. On the other hand, it reaches CCD6, a part of other outgoing radiation light from an optical fiber 3 being too used as parallel light with a lens 5 as the flux of light for reference. And in respect of light-receiving of CCD6, the flux of light for reference and the flux of light for measurement reflected in the measuring-plane-ed 4 list by optical Ferber's 3 outgoing radiation end face interfere mutually, and produces an interference fringe.

[0027] Moreover, in this example, in order to raise the accuracy of measurement, the piezo-electric element 11 is arranged by the holder of the measuring plane 4-ed, the measuring plane 4-ed can be minutely vibrated in the direction of an optical axis, and the profile irregularity of the measuring plane 4-ed can be read to high degree of accuracy by the technique of well-known AC interferometer.

[0028] In addition, in this example, although the optical path lengths of the flux of light for measurement and the flux of light for reference differ, if the coherent good light source of single wavelength laser etc. is used as the light source 1, the difference of the optical path length of this level will not become a measurement top problem.

[0029] By the way, the accuracy of measurement of this example is decided by precision of the outgoing radiation wave front of the outgoing radiation light from an optical fiber 3. the time of the path (diameter) phi of the core of an optical fiber setting the radius of curvature of the operating wavelength lambda and a measuring plane-ed to r, and setting the aperture to a here -- following (1) if the relation of a formula is filled, since it can be considered that the outgoing radiation wave front from here is an ideal spherical wave -- $\lambda / 100 - \lambda / 1000$ -- profile irregularity can be measured in a high precision to say.

[0030]

$$\lambda/2 < \phi < \lambda/2a \quad (1)$$

[0031] Therefore, this (1) At the conditions of a formula to this example, it is the path of core 3a of a single mode optic fiber 3 $\phi = 6 \mu m$ and $\lambda = 0.6$ If μm , as for the relation with the measuring plane 4-ed, it will become conditions that r/a is those [20 or more].

[0032] Next, the single mode optic fiber 3 of this example is core 3a and a diameter with a diameter of several micrometers, as shown in drawing 2 . It consists of about 100 micrometers clad 3b, and is fixed in fixture 3c for immobilization for optical connectors etc. And the flux of light for measurement reflected by the measuring plane 4-ed as mentioned above is reflected near the clad 3b of an optical-fiber outgoing radiation end face.

[0033] Since this flux of light for measurement is reflected in respect of two, the measuring plane 4-ed and a fiber end face, (only in case of part), the quantity of light is declining compared with the flux of light for reference which is not reflected once, and the contrast of the interference fringe produced in the light-receiving side of CCD6 becomes low. In this case, if a piezo-electric element is worked and the technique of AC interferometer is used, it is measurable also in the interference fringe of low contrast.

[0034] However, since too much low contrast becomes the factor which worsens the accuracy of measurement, it is raising the reflective effectiveness of the flux of light for measurement, and it is possible to raise the contrast (quantity of light of the flux of light for measurement) of an interference fringe. For this reason, in other examples, coating (not shown) is carried out to the clad section of an optical-fiber end face, and solution of this problem is in drawing by raising a reflection factor. Moreover, since the metallic fixture 3c front face for immobilization has a high reflection factor, the flux of light for measurement may be reflected by making this into the light reflex section here. Anyway, the portion which reflects the flux of light for measurement of the optical-fiber end-face section needs to be sufficiently good profile irregularity within the limits of the spot.

[0035] Since a pinhole is not used like the example of precedence according to this example as mentioned above while being able to use the flux of light from the light source 1 without futility, the optical system itself has been simplified. Moreover, problems accompanying a drift peculiar to a laser beam etc., such as the stability of the light source and quantity of light loss, are also solved, and it has become the profile irregularity measuring device which can measure profile irregularity in a very high precision.

[0036] In addition, according to this example, the advantage which can make the configuration of an interferometer very flexible is in a measuring device list. For example, if the optical fiber of this example is lengthened, it is possible to measure profile irregularity in the location fully distant from the light source 1, and the compact interferometer which is

not influenced by the magnitude of the light source section can be constituted. It became possible to constitute the stable measuring device which does not have effect of pyrexia of the light source 1, an oscillation, etc. on a measuring plane-ed from furthermore separating the light source 1 from an interferometer portion in this case.

[0037] Moreover, as an optical fiber, if a plane-of-polarization conservation fiber is used, the flux of light in the condition of having maintained the polarization condition of the light source 1 can be used for measurement. In this case, not only profile irregularity but the thing to apply to measurement of the thickness (homogeneity) of the coating member which applied the birefringence operation based on the flux of light which polarized etc., for example, was given on the surface of the spherical surface etc. is possible.

[0038] Next, the example using optical waveguide as a solid-state optical transmission line is shown in drawing 3. In this example, the single mode waveguide 37 is formed on the substrate, and the magnitude of this waveguide section is formed in several microns. And the operation same with using the single mode optic fiber mentioned above can be acquired by using the flux of light by which outgoing radiation is carried out from here. In addition, these arrangement configurations are the same as that of the above-mentioned example in the measuring plane 4-ed in this example, a lens 5, and piezo-electric element 11 list.

[0039] By the way, although incidence of the light from a laser light source 31 is carried out to optical waveguide 37 through the element 32 condensing [optical] in the example shown in drawing 3, it is also possible to use semiconductor laser as the light source, and it is also possible to combine the light source and optical waveguide 37 direct without a lens in this case. Furthermore, it is also possible to unify semiconductor laser on the substrate of optical waveguide 37 at a monolithic, and the miniaturization by integration of a light source means can be attained. In addition, it cannot be overemphasized that the coherent good light source is used for the light source in any case.

[0040] Moreover, the so-called technique of AC interferometer can also be used by preparing an electrode on a waveguide substrate and performing a phase modulation on optical waveguide 37, without using a piezo-electric element.

[0041] Thus, it is possible to form a very small measuring device in this example list according to the application, and if an interference fringe is only observed by direct viewing, without using the detection means of CCD6 grade especially, a micro measuring device with a magnitude of several mm which consists only of the semiconductor laser light source and optical waveguide is realizable.

[0042] Next, the outline configuration of the spherical-surface configuration measuring device directly applied to the example using the outgoing radiation light from the light source as other examples of this invention is shown in drawing 4. In this example, semiconductor laser 48 was used as the light source, and the outgoing radiation light from this semiconductor laser 48 is used for the flux of light for reference at the flux of light list for direct measurement. In addition, these arrangement configurations are the same as that of the above-mentioned example in the measuring plane 4-ed in this example, a lens 5, and piezo-electric element 11 list.

[0043] As shown in drawing 4, in this example, the measuring plane 4-ed on which a part of outgoing beam which carried out outgoing radiation made the optical axis of semiconductor laser 48 and the predetermined angle as the flux of light for measurement as it was, and it was put from semiconductor laser 48 is irradiated directly. The flux of light for measurement reflected by the measuring plane 4-ed is condensed by the outgoing radiation end face of semiconductor laser 48 through the optical path which came origin. And it is again reflected by the end face of semiconductor laser 48, and this condensed light serves as the parallel flux of light with a lens 5, and arrives at the light-receiving side of CCD6. Moreover, it reaches CCD6 directly, a part of other outgoing beams from semiconductor laser 48 being used as parallel light with a lens 5 as the flux of light for reference as they are. And in respect of light-receiving of CCD6, the flux of light for reference and the flux of light for measurement reflected by the measuring plane 4-ed interfere mutually, and an interference fringe arises.

[0044] By the way, recently semiconductor laser with little astigmatism is developed, and since development of a surface emission-type laser without astigmatism is also furthered, it is desirable [a general outgoing radiation light (outgoing radiation wave front) of semiconductor laser], although it is known that it is a wave front with not an ideal spherical wave but astigmatism to use such a thing for this interferometer.

[0045] However, in using general semiconductor laser, by making the angle which the optical axis of the measuring plane 4-ed and the optical axis of semiconductor laser 8 make equal to the angle which the optical axis of a lens 5 and the optical axis of semiconductor laser 8 make using the astigmatism in an outgoing beam being symmetrical with reversal to the optical axis of semiconductor laser, it is possible to cancel astigmatism mutually and existence of these astigmatism does not become a problem actually.

[0046] Here, the semiconductor laser of a general double heterojunction is taken for an example, and the condition of the light by which outgoing radiation is carried out from here is shown in drawing 5. As shown in this drawing, the

outgoing radiation light from semiconductor laser has a big angle of divergence (40-60 degrees) in the direction (the direction of z) vertical to a barrier layer, and, horizontally (the direction of y), has small breadth (about 10 degrees). For this reason, while leaning the optical axis of the flux of light for measurement (measuring plane 4-ed) in the direction vertical to the barrier layer of semiconductor laser if arrangement of each part material is taken into consideration in attaining the object which negates astigmatism like this example, it is desirable to lean the optical axis of the flux of light for reference (lens 5) in it and the symmetrical direction.

[0047] Furthermore, since it is usually ground in the precision more than wavelength, reflective effectiveness will become quite high, but since the outgoing radiation end face of semiconductor laser 48 can reflect efficiently the flux of light for measurement reflected by the measuring plane 4-ed by performing mirror plane processing except for the optical outgoing radiation section, it becomes easy to measure [of an interference fringe] it.

[0048] Moreover, also with the measuring device concerning this example, the measuring plane-ed was minutely vibrated in the direction of an optical axis by the piezo-electric element 11, and the profile irregularity of a measuring plane-ed can be read to high degree of accuracy by the technique of well-known AC interferometer. Here, also by modulating the wavelength of semiconductor laser 48, it is possible to use the technique of AC interferometer and the measuring device which does not have ***** in this case can be constituted.

[0049] In addition, although the optical path lengths of the flux of light for measurement and the flux of light for reference differ, since the semiconductor laser light source 48 is generally single wavelength laser and this example is also the coherent good light source, the difference of the optical path length of this level does not become a problem.

[0050] As mentioned above, according to this example, it is possible to build the measuring device of simpleest configuration of to become the lens 5 list used as the light source 8 and an interference fringe image formation system only from CCD6.

[0051]

[Effect of the Invention] As explained above, it is not necessary to amend the effect of the aberration of optical system like [according to this invention] the equipment adapting the conventional common interferometer using a spherical-surface gage, and with these equipments, there is an advantage which can measure the profile irregularity in a high precision which was not acquired.

[0052] Since many problems, such as quantity of light loss of alignment with precise problem on the fabrication of a precise pinhole and optical system using this and the light source accompanying these and stability, are solved like the example of precedence on the other hand and the optical system of a light source means serves as a simple configuration, general operation can carry out very easily.

[0053] Furthermore, since a commercial optical fiber etc. can be easily used as a solid-state optical transmission line and commercial semiconductor laser can be used also for the light source as it is, the manufacturing cost also decreased substantially and the fabrication process has also simplified it. In addition, the profile irregularity measuring device which it is small and is easy to treat is realizable by establishing solid-state optical transmission lines, such as the light source, an optical fiber, and optical waveguide, in one, and integrating.

[0054] Moreover, if a solid-state optical transmission line is extended, while it is possible to arrange the light source in the location distant from the interference fringe image formation system of equipment and the flexibility of layout improves, the utilization range of an interferometer will be expanded, for example, utilization in fabrication sites, such as a lens, will become easy. Furthermore, since the effect of the oscillation of the light source etc. can be eliminated to an interference fringe image formation system etc. in this case, it is hard to produce the error of the accuracy of measurement.

[Translation done.]

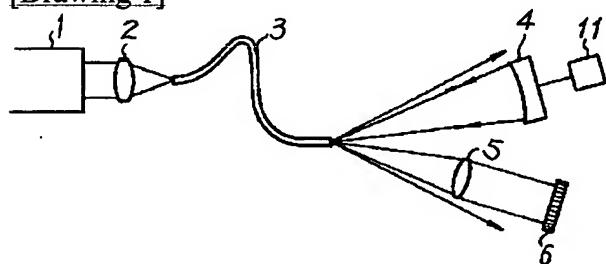
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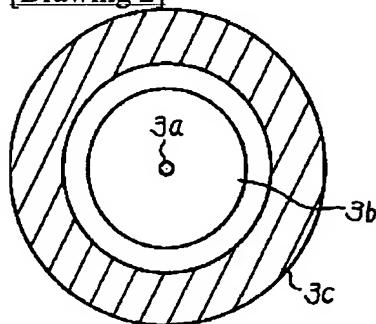
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DRAWINGS

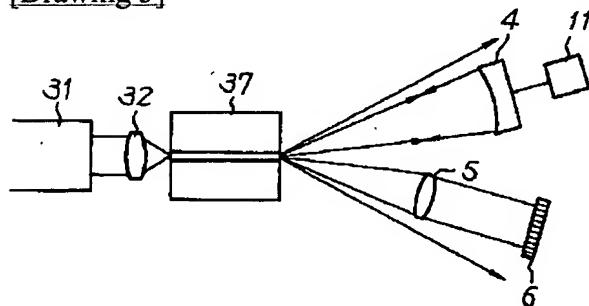
[Drawing 1]



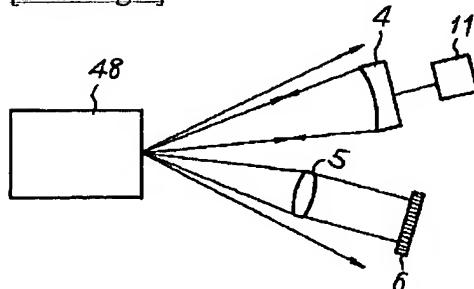
[Drawing 2]



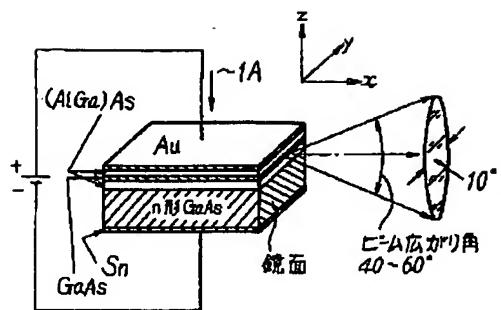
[Drawing 3]



[Drawing 4]



[Drawing 5]



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CORRECTION OR AMENDMENT

[Official Gazette Type] Printing of amendment by the convention of 2 of Article 17 of patent law

[Category partition] The 1st partition of the 6th category

[Date of issue] June 22, Heisei 13 (2001. 6.22)

[Publication No.] JP,6-174447,A

[Date of Publication] June 24, Heisei 6 (1994. 6.24)

[Year copy format] Open patent official report 6-1745

[Filing Number] Japanese Patent Application No. 4-343599

[The 7th edition of International Patent Classification]

G01B 11/24

9/02

[FI]

G01B 9/02

[Procedure amendment]

[Filing Date] October 4, Heisei 11 (1999. 10.4)

[Procedure amendment 1]

[Document to be Amended] Description

[Item(s) to be Amended] Claim

[Method of Amendment] Modification

[Proposed Amendment]

[Claim(s)]

[Claim 1] In a profile irregularity measuring device which measures profile irregularity of said measuring plane-ed by arranging a concave surface used as a measuring plane-ed in an exposure location of the flux of light from a light source means, making the flux of light for measurement reflected by this measuring plane-ed, and the flux of light for reference interfere mutually, and detecting a condition of an interference fringe produced by this interference,

A profile irregularity measuring device characterized by using the flux of light which has a solid-state optical transmission line which transmits an outgoing beam of said light source means, and carries out outgoing radiation from the optical outgoing radiation section of this optical transmission line as said flux of light for measurement, and the flux of light for reference.

[Claim 2] In a profile irregularity measuring device which measures profile irregularity of said measuring plane-ed by arranging a concave surface used as a measuring plane-ed in an exposure location of the flux of light from a light source means, making the flux of light for measurement reflected by this measuring plane-ed, and the flux of light for reference interfere mutually, and detecting a condition of an interference fringe produced by this interference,

A profile irregularity measuring device characterized by using directly the flux of light by which direct outgoing radiation is carried out, without said light source means minding space from this semiconductor laser including semiconductor laser as said flux of light for measurement, and the flux of light for reference.

[Claim 3] A profile irregularity measuring device according to claim 2 characterized by being constituted so that an optical axis of the flux of light for measurement and the flux of light for reference by which direct outgoing radiation is

carried out may serve as axial symmetry from said semiconductor laser mutually to an optical axis of said semiconductor laser.

[Claim 4] A profile irregularity measuring device according to claim 1, 2, or 3 characterized by preparing the light reflex section in a location near the optical outgoing radiation section of said light source means.

[Procedure amendment 2]

[Document to be Amended] Description

[Item(s) to be Amended] 0001

[Method of Amendment] Modification

[Proposed Amendment]

[0001]

[Industrial Application] This invention relates to profile irregularity measurement **** which measures concave profile irregularity.

[Procedure amendment 3]

[Document to be Amended] Description

[Item(s) to be Amended] 0008

[Method of Amendment] Modification

[Proposed Amendment]

[0008]

[Means for Solving the Problem] For the above-mentioned object achievement, invention of a publication to this application claim 1 By arranging a concave surface used as a measuring plane-ed in an exposure location of the flux of light from a light source means, making the flux of light for measurement reflected by this measuring plane-ed, and the flux of light for reference interfere mutually, and detecting a condition of an interference fringe produced by this interference In a profile irregularity measuring device which measures profile irregularity of said measuring plane-ed, a solid-state optical transmission line which transmits an outgoing beam of said light source means is prepared, and the flux of light which carries out outgoing radiation from the optical outgoing radiation section of this optical transmission line is used as said flux of light for measurement, and the flux of light for reference.

[Procedure amendment 4]

[Document to be Amended] Description

[Item(s) to be Amended] 0009

[Method of Amendment] Modification

[Proposed Amendment]

[0009] Moreover, the flux of light for measurement which has arranged the concave surface used as a measuring plane-ed in the exposure location of the flux of light from a light source means, and was reflected in it by this measuring plane-ed in invention according to claim 2, By making the flux of light for reference interfere mutually, and detecting the condition of an interference fringe produced by this interference In the profile irregularity measuring device which measures the profile irregularity of said measuring plane-ed, said light source means is built by semiconductor laser, and the flux of light by which direct outgoing radiation is carried out, without minding space from this semiconductor laser is directly used as said flux of light for measurement, and the flux of light for reference.

[Procedure amendment 5]

[Document to be Amended] Description

[Item(s) to be Amended] 0045

[Method of Amendment] Modification

[Proposed Amendment]

[0045] However, in using general semiconductor laser, by making the angle which the optical axis of the measuring plane 4-ed and the optical axis of semiconductor laser 48 make equal to the angle which the optical axis of a lens 5 and the optical axis of semiconductor laser 48 make using the astigmatism in an outgoing beam being symmetrical with reversal to the optical axis of semiconductor laser, it is possible to cancel astigmatism mutually and existence of these astigmatism does not become a problem actually.

[Procedure amendment 6]

[Document to be Amended] Description

[Item(s) to be Amended] 0050

[Method of Amendment] Modification

[Proposed Amendment]

[0050] As mentioned above, according to this example, it is possible to build the measuring device of simplest

configuration of to become the lens 5 list used as the semiconductor laser 48 which is the light source, and an interference fringe image formation system only from CCD6.

[Translation done.]